Inter (Part-I) 2018

Physics	Group-II	PAPER: I
Time: 2.40 Hours	(SUBJECTIVE TYPE)	Marks: 68

SECTION-I

2. Write short answers to any EIGHT (8) questions: (16)

(i) Calculate the distance covered by the light in free space in one year.

Ans **Data:**

v = Velocity of light = $c = 3.0 \times 10^8\ ms^{-1}$ (constant)

Time = $t = 365 \times 24 \times 60 \times 60 = 31536000$ sec

To Calculate:

Distance = S = ?

Formula:

Velocity is constant. So, formula used will be:

$$S = vt$$

Calculation:

$$S = vt = ct$$
$$= (3 \times 10^8)(31536000)$$
$$= 9.46 \times 10^{15}\ m$$

Rounded off answer is:

$$= 9.5 \times 10^{15}\ m$$

(ii) Show that the Einstein's equation $E = mc^2$ is dimensionally correct.

Ans **Data:**

Given equation is $E = mc^2$

To Determine:

Equation is dimensionally consistent.

Since, $E = mc^2$

where c is velocity of light.

Dimensions of energy are that of work.

Therefore, dimensions of L.H.S. = $[E] = [ML^2T^{-2}]$

Dimensions of R.H.S. = $[mc^2] = [M(LT^{-1})^2] = [ML^2T^{-2}]$

Hence, Dimensions of LHS = dimensions of RHS

So, above equation is dimensionally correct.

(iii) What do you mean by random error and systematic error?

Ans **Random error:**

Random error is said to be occur, when repeated measurements of a quantity, give different values under the same conditions.

Systematic error:

Systematic error is said to be occur, when all measurements of a particular quantity are affected equally. It produces a consistent difference in readings.

(iv) Add the following up to appropriate precision 3.125, 1.2, 0.038.

Ans Given,

$$= 3.125, 1.2, 0.038$$

Proof:

By adding,

$$= 3.125 + 1.2 + 0.038$$
$$= 4.363$$

The appropriate precision is 4.3.

(v) What is the unit vector in the direction of vector $\vec{A} = 2\hat{i} - \hat{j} + 2\hat{k}$?

Ans As we know

$$\hat{A} = \frac{\vec{A}}{|A|}$$

$$\vec{A} = 2\hat{i} - \hat{j} + 2\hat{k}$$

$$|A| = \sqrt{(2)^2 + (-1)^2 + (2)^2}$$
$$= \sqrt{4 + 1 + 4}$$
$$= \sqrt{9}$$
$$|A| = 3$$

$$\hat{A} = \frac{2\hat{i} - \hat{j} + 2\hat{k}}{3}$$

$$\boxed{\hat{A} = \frac{2}{3}\hat{i} - \frac{1}{3}\hat{j} + \frac{2}{3}\hat{k}}$$

(vi) Can the dot product of two vectors be equal to the product of their magnitudes? Explain.

Ans According to third characteristic of scalar or dot product, the dot product of two parallel vectors is equal to the product of their magnitudes. Thus, for parallel vectors ($\theta = 0^\circ$)

$$A.B = AB\cos 0^\circ = AB$$

(vii) State first and second condition of equilibrium along with their equation.

Ans **1st condition:**

The vector sum of all forces acting on it must be zero.

Mathematically, $\Sigma F = 0$.

2nd condition:

For a body in equilibrium, the vector sum of all the torques acting on it about any arbitrary axis should be zero.

Mathematically, $\Sigma \tau = 0$.

(viii) Water flows out from a pipe at 5 kgs⁻¹ and its velocity changes from 4 ms⁻¹ to zero on striking the wall. Find the force exerted by the water on the wall.

Ans

$$\text{Mass} = \frac{m}{t} = 5\ \text{kgs}^{-1}$$

$$\text{Velocity} = v = 4\ \text{ms}^{-1}$$

$$\text{Force} = F = ?$$

$$\text{Force} = \text{Change in momentum per second}$$

$$= 5\ \text{kgs}^{-1} \times 4\ \text{ms}^{-1}$$

$$= 20\ \text{kgms}^{-2}$$

$$= 20\ \text{N}$$

(ix) Show that range R and maximum range R_{max} are related as $\frac{R}{R_{max}} = \sin 2\theta$.

Ans As range of projectile is given by:

$$R = \frac{v_i^2}{g}\sin 2\theta \qquad \text{(i)}$$

The maximum horizontal range is,

$$R_{max} = \frac{v_i^2}{g} \qquad \text{(ii)}$$

Putting $R_{max} = \frac{v_i^2}{g}$ in equation (i)

$$R = R_{max} \sin 2\theta$$

$$\frac{R}{R_{max}} = \sin 2\theta$$

Hence proved.

(x) Can the velocity of an object reverse the direction when acceleration is constant? If so, give an example.

Ans Yes, the velocity of an object can reverse the direction when acceleration is constant.

Example:

When an object is thrown vertically upward, the velocity reverses its direction at maximum height, when the body starts falling downward. But the acceleration of the body remains constant through out its motion equal to 9.8 ms^{-2}.

(xi) Define viscosity and drag force.

Ans **Viscosity:**

The internal friction between the different layers of flowing fluid is called viscosity of the fluid.

Drag Force:

An object moving through a fluid experiences a retarding force called a drag force or viscous drag.

(xii) Explain the working of carburetor of a motorcar using Bernoulli's principle.

Ans The carburetor of a car uses a venturi duct to feed the correct mixture of air and petrol to the cylinders. Air is drawn through the duct and along a pipe to the cylinder. A tiny inlet at the side of the duct is fed with petrol. The air through the duct moves very fast creating a low pressure in the duct which draws petrol vapours into the air stream that goes to the cylinder.

3. Write short answers to any EIGHT (8) questions: (16)

(i) Derive work energy principle.

Ans From equation of motion,

$$2ad = v_f^2 - v_i^2$$

or $$d = \frac{1}{2a}(v_f^2 - v_i^2) \quad \text{(i)}$$

From second law of motion,

$$F = ma \quad \text{(ii)}$$

Multiplying equations (i) & (ii), we have

$$Fd = \frac{1}{2}m(v_f^2 - v_i^2)$$

or $$\boxed{F\,d = \frac{1}{2}m\,v_f^2 - \frac{1}{2}mv_i^2}$$

(ii) Explain methods of:
(i) Direct combustion.
(ii) Fermentation to convert biomass into fuels.

Ans **(i) Direct Combustion:**

Direct combustion method is usually applied to get energy from waste products commonly known as solid waste.

(ii) Fermentation:

Biofuel such as ethanol (alcohol) is a replacement of gasoline. It is obtained by fermentation of biomass using enzymes and by decomposition through bacterial action in the absence of air (oxygen).

(iii) A cup is dropped from a certain height, which breaks into pieces. What energy changes are involved?

Ans When a cup is dropped from certain height which breaks into pieces, the potential energy is changed into the kinetic energy. Sound and heat energy are also produced.

(iv) When mud flies off the tyre of a moving bicycle, in what direction does it fly?

Ans The mud will fly off tangentially along a straight line. When the tyre rotates, a centripetal force acts on the mud which is equal to the adhesive force between the tyre and mud. When the angular speed of the tyre increases, the centripetal force on the mud also increases. When this centripetal force is greater than the adhesive force, the mud leaves the tyre and flies off tangentially along a straight line due to centrifugal force, which is simply the reaction of the centripetal force.

(v) What is difference between spin angular momentum and orbital angular momentum?

Ans The angular momentum of a spinning body is called spin angular momentum. It is denoted by L_s.

The angular momentum of a body moving in a circle is called orbital angular momentum. It is denoted by L_o.

(vi) Define radian and find how many degrees are in one radian.

Ans The angle subtended by an arc at the centre of the circle whose length is equal to the radius of the circle is called radian.

Consider a particle P is moving in a circle of radius 'r'. In one revolution, the distance covered by the particle is $2\pi r$.

i.e., $S = 2\pi r$

Using the equation $S = r\theta$, we can write:

$$\theta = \frac{S}{r} = \frac{2\pi r}{r}$$

$$\theta = 2\pi \text{ radian} \qquad \text{(i)}$$

In one revolution, $\theta = 360^\circ$ (ii)

From (i) & (ii),

$$2\pi \text{ radian} = 360^\circ$$

$$1 \text{ radian} = \frac{360^\circ}{2\pi}$$

$$\boxed{1 \text{ radian} = 57.3^\circ}$$

(vii) Does period depend on amplitude of vibrating body? Explain.

Ans Dividing the total time by the total number of vibrations, we get the time for one vibration of pendulum. The time period of a pendulum depends only on the length of pendulum. It does not depend on amplitude of vibrations.

(viii) Define restoring force and what is its direction?

Ans The force that brings the body back to its equilibrium position is called restoring force. If the system is perturbed away from the equilibrium, the restoring force will tend to bring the system back towards equilibrium.

(ix) **At which positions the velocity of a simple harmonic oscillator is maximum and minimum?**

Ans At mean position, where $x = 0$, the velocity is maximum and at the extreme position where $x = x_0$, the velocity is zero or minimum.

(x) **How are beats useful in tuning musical instruments?**

Ans One can use beats to tune a string instrument, such as piano or violin, by beating a note against a note of known frequency. The string can then be adjusted to the desired frequency by tightening or loosening it until no beats are heard.

(xi) **Astronomers use the Doppler effect to calculate the speed of distance stars. How?**

Ans Astronomers use the Doppler effect to calculate the speed of distant stars and galaxies. By comparing the line spectrum of light from star with light from a laboratory source, the Doppler shift of the star's light can be measured. Then, the speed of the star can be calculated.

(xii) **What is the affect on phase of a wave when it is reflected from a boundary?**

Ans When a wave is reflected from a boundary, the reflected wave has the same wavelength and frequency but its phase may change depending upon the nature of the boundary.

4. Write short answers to any SIX (6) questions: (12)

(i) **Under what conditions two or more sources of light behave as coherent sources?**

Ans Two or more sources of light behave as coherent sources, if they have no phase difference or have a constant phase difference between the waves emitted by them. It is produced by using single source to illuminate a screen containing two narrow slits.

(ii) **Why the Polaroid sunglasses are better than ordinary sunglasses?**

Ans When light passes through plane polarized glasses, a polarized light is obtained. For example, light reflected from a surface produces lesser glare. In the same way,

the glare of light can be reduced by using polaroid glasses. Hence, the polaroid sunglasses are better than ordinary sunglasses.

(iii) An oil film spreading over a wet footpath shows colours. Explain how does it happen?

Ans These colours are seen due to interference of light.

It happens when the rays of white light fall on the surface of oil film. The rays of light reflected from upper and lower surface of oil film interfere destructively. Thus, due to this reason, coloured fringes appear.

(iv) One can buy a cheap microscope for the use by the children. The images seen in such a microscope have coloured edges. Why is this so?

Ans The image seen in the cheap microscope has the coloured edges due to chromatic defect in the lenses used in the microscope. The lenses disperse the light into different colours due to which the coloured image is formed.

(v) How the light signal is transmitted through the optical fibre?

Ans In an optical fibre:

1. A transmitter converts sound signal into electrical signal and then this electrical signal into light signal.
2. Optical fibre which transmits light signals by total internal reflection and continuous refraction.

(vi) Give an example of a natural process that involves an increase in entropy.

Ans When ice is melted due to high temperature of surroundings, the heat is transferred to ice from surroundings is positive. Since, $\Delta S = \frac{\Delta Q}{T}$. As ΔS is positive, thus entropy of natural process increases

(vii) Why is the average velocity of the molecules in a gas zero but the average of the square of velocities is not zero?

Ans There are a large number of molecules in a gas and according to the kinetic molecular theory of gases, equal

number of molecules move in all directions. This means that number of molecules moving in one direction is equal to the number of molecules moving in the opposite direction. Thus, the vector sum of their velocities is zero. But the square of negative velocity is positive. Therefore, the average of the square of the velocities is not zero.

(viii) Give the statement of second law of thermodynamics and Carnot's theorem.

Ans **2^{nd} law of thermodynamics:**

It is impossible to devise a process which may convert heat, extracted from a single reservoir, entirely into work without leaving any change in the working system.

Carnot's theorem:

No heat engine can be more efficient than Carnot engine operating between the same two temperatures.

(ix) Is it possible to convert internal energy into mechanical energy? Explain with an example.

Ans Yes, in adiabatic expansion, internal energy is changed into mechanical energy. According to 1st law of thermodynamics,

$$Q = \Delta U + W \qquad \because Q = 0$$

$$0 = \Delta U + W$$

$$W = -\Delta U$$

Example:

In petrol engine, hot gases expand and piston moves, so internal energy is converted into work.

SECTION-II

NOTE: Attempt any Three (3) questions.

Q.5.(a) Define vector product or cross product. Explain with right hand rule and give four characteristics of cross product. (5)

Ans Vector or Cross product:

If the product of two vector quantities is a vector quantity, than the product is called vector product.

The vector product of two vectors A and B, is a vector which is defined as.

$$A \times B = AB \sin\theta \, \hat{n}$$

where $\hat{n}$ is a unit vector perpendicular to the plane containing A and B as shown in Fig. (a).

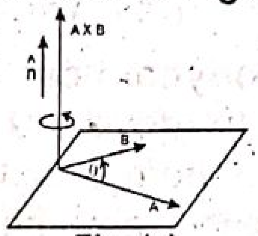


Fig. (a)

Its direction can be determined by right hand rule. For that purpose, place together the tails of vectors A and B to define the plane of vectors A and B. The direction of the product vector is perpendicular to this plane. Rotate the first vector A into B through the smaller of the two possible angles and curl the fingers of the right hand in the direction of rotation, keeping the thumb erect. The direction of the product vector will be along the erect thumb, as shown in the Fig. (b).

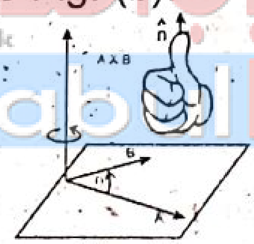


Fig. (b)

Because of this direction rule, B × A is a vector opposite in sign to A × B. Hence,

$$A \times B = -B \times A$$

Characteristics of Cross Product:

1. Since, A × B is not the same as B × A, the cross product is non-commutative.
2. The cross product of two perpendicular vectors has maximum magnitude $A \times B = AB \sin 90^\circ = \hat{n} = AB\,\hat{n}$. In case of unit vectors, since they form a right

handed system and are mutually perpendicular. See Fig. (c) below:

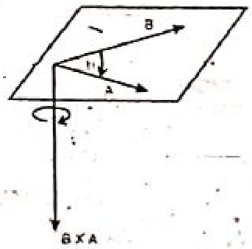


Fig. (c)

$$\hat{i} \times \hat{j} = \hat{k},\ \hat{j} \times \hat{k} = \hat{i},\ \hat{k} \times \hat{i} = \hat{j}$$

3. The cross product of two parallel vectors is null vector, because for such vectors $\theta = 0^\circ$ or 180°. Hence,

$$A \times B = AB \sin 0^\circ\, \hat{n} = AB \sin 180^\circ\, \hat{n} = 0$$

As a consequence, $A \times A = 0$

Also $\hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = 0$

4. Cross product of two vectors A and B in terms of their rectangular components is:

$$A \times B = (A_x \hat{i} + A_y \hat{j} + A_z \hat{k}) \times (B_x \hat{i} + B_y \hat{j} + B_z \hat{k})$$

$$A \times B = (A_y B_z - A_z B_y)\hat{i} + (A_z B_x - A_x B_z)\hat{j} + (A_x B_y - A_y B_x)\hat{k}$$

The result obtained can be expressed for memory in determinant form as below:

$$A \times B = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

5. The magnitude of $A \times B$ is equal to the area of the parallelogram formed with A and B as two adjacent sides as shown in the following Fig. (d):

Fig. (d).

(b) Find angle of projection of a projectile for which its maximum height and the horizontal range are equal. (3)

Ans **Data:**

Maximum height = Horizontal range

To Find:

Angle of projection = θ = ?

Formula:

$$\text{Maximum height} = h = \frac{v_i^2 \sin^2\theta}{2g}$$

$$\text{Range of projectile} = R = \frac{v_i^2 \sin 2\theta}{g}$$

Calculations:

According to the question

$$h = R$$

Putting the values, we get

$$\frac{v_i^2 \sin^2\theta}{2g} = \frac{v_i^2 \sin 2\theta}{g}$$

or $\quad \dfrac{\sin^2\theta}{2} = \sin 2\theta \qquad (\sin 2\theta = 2\sin\theta\cos\theta)$

or $\quad \dfrac{\sin^2\theta}{2} = 2\sin\theta.\cos\theta$

$$\frac{\sin\theta}{\cos\theta} = 4$$

or $\quad \tan\theta = 4$

or $\quad \theta = \tan^{-1}(4) = 76°$

$\therefore \quad \boxed{\theta = 76°}$ Ans.

Result:

The angle of projection of a projectile is 76°.

Q.6.(a) What is absolute gravitational potential energy? Derive an expression for it. (5)

Ans The absolute gravitational potential energy of an object at a certain position is the work done by the gravitational force in displacing the object from that position to infinity where the force of gravity becomes zero. The relation for the calculation of the work done by the gravitational force or potential energy = mgh, is true

only near the surface of the Earth, where the gravitational force is nearly constant. But if the body is displaced through a large distance in space from, let, point 1 to N in the gravitational field, then the gravitational force will not remain constant, since it varies inversely to the square of the distance.

In order to overcome this difficulty, we divide the distance between points 1 and N into small steps, each of length Δr so that the value of the force remains constant for each small step. Hence, the total work done can be calculated by adding the work done during all these steps. If r_1 and r_2 are the distances of points 1 and 2, respectively, from the centre O of the Earth, the work done during the first step *i.e.*, displacing a body from point 1 to point 2 can be calculated as below.

The distance between the centre of this step and the centre of the Earth will be:

$$r = \frac{r_1 + r_2}{2}$$

if $\quad r_2 - r_1 = \Delta r \quad$ then, $\quad r_2 = r_1 + \Delta r$

$$\text{Hence, } r = \frac{r_1 + r_1 + \Delta r}{2} = r_1 + \frac{\Delta r}{2} \qquad \text{(i)}$$

The gravitational force F at the centre of this step is

$$F = G\frac{Mm}{r^2} \qquad \text{(ii)}$$

where $\quad$ m = mass of an object

M = mass of the Earth

and $\quad$ G = Gravitational constant

Squaring equation (i),

$$r^2 = \left(r_1 + \frac{\Delta r}{2}\right)^2$$

$$r^2 = r_1^2 + 2r_1\frac{\Delta r}{2} + \left(\frac{\Delta r}{2}\right)^2$$

As $(\Delta r)^2 << r_1^2$, so this term can be neglected as compared to r_1^2

Hence, $r^2 = r_1^2 + r_1\Delta r$

Substituting the value of Δr,

$$r^2 = r_1^2 + r_1(r_2 - r_1) = r_1 r_2$$

Hence, equation (ii) becomes:

$$F = G\frac{Mm}{r_1 r_2} \qquad \text{(iii)}$$

As the force is assumed to be constant during the interval Δr, so the work done is,

$$W_{1\to 2} = F.\Delta r = F\Delta r \cos 180^\circ = -GMm\frac{\Delta r}{r_1 r_2}$$

The negative sign indicates that the work has to be done on the body from point 1 to 2 because displacement is opposite to gravitational force. Putting the value of Δr, we get,

$$W_{1\to 2} = -GMm\frac{r_2 - r_1}{r_1 r_2}$$

$$\text{or } W_{1\to 2} = -GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

Similarly, the work done during the second step in which the body is displaced from point 2 to 3 is:

$$W_{2\to 3} = -GMm\left(\frac{1}{r_2} - \frac{1}{r_3}\right)$$

and the work done in the last step is,

$$W_{N-1\to N} = -GMm\left(\frac{1}{r_{N-1}} - \frac{1}{r_N}\right)$$

Hence, the total work done in displacing a body from point 1 to N is calculated by adding up the work done during all these steps.

$$W_{total} = W_{1\to 2} + W_{2\to 3} + \ldots\ldots + W_{N-1\to N}$$

$$= -GMm\left[\left(\frac{1}{r_1}-\frac{1}{r_2}\right)+\left(\frac{1}{r_2}-\frac{1}{r_3}\right)+\ldots\ldots+\left(\frac{1}{r_{N-1}}-\frac{1}{r_N}\right)\right]$$

On simplification, we get,

$$W_{total} = -GMm\left(\frac{1}{r_1}-\frac{1}{r_N}\right)$$

If the point N is situated at an infinite distance from the Earth, so,

$$r_N = \infty \quad , \quad \text{then} \quad \frac{1}{r_N} = \frac{1}{\infty} = 0$$

$$\text{Hence, } W_{total} = \frac{-GMm}{r_1}$$

Therefore, the general expression for the gravitational potential energy of a body situated at distance r from the centre of Earth is,

$$U = \frac{-GMm}{r}$$

This is also known as the absolute value of gravitational potential energy of a body at a distance r from the centre of the Earth.

(b) What would be the orbiting speed to launch a satellite in a circular orbit 900 km above the surface of the earth? Mass of earth = 6×10^{24} kg, Radius of earth = 6400 km. (3)

Ans

Height of satellite	=	$h = 900$ km
Radius of earth	=	$R = 6400$ km
Mass of earth	=	$M = 6 \times 10^{24}$ kg
Orbit speed	=	$v = ?$
G	=	$6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$

Total distance of satellite from centre of the earth

$$r = h + R$$
$$= 900 + 6400 = 7300 \text{ km}$$
$$= 7300{,}000 \text{ m}$$

We know that speed of the launch of a satellite is given as:

$$v = \sqrt{\frac{GM}{r}}$$

$$v = \sqrt{\frac{(6.67 \times 10^{11})(6 \times 10^{24})}{7300000}}$$

$$v = 7.4 \times 10^3 \text{ m/sec}$$

$$\text{or} \quad v = 7.4 \text{ km/sec}$$

Q.7.(a) Define and explain entropy with an example. Does entropy decrease for reversible process? Why absolute value of entropy cannot be determined? (5)

Ans The entropy of a system can be defined as "The thermal property of system which remains constant when no heat enters or leaves the system."

Entropy is a state variable and it describes "The unavailability of the energy from the system to do work."

Measurement of Change in Entropy:

If a system absorbs or rejects heat ΔQ at absolute temperature T, the change in entropy of the system is given by,

$$\Delta S = \frac{\Delta Q}{T}$$

The change in entropy ΔS is positive when heat ΔQ is added to a system and negative when heat ΔQ is removed from the system.

All real processes taking place in the universe are either reversible or irreversible. During a reversible process, the entropy of the system remains constant where it increases during all irreversible process. If entropy of a system decreases during a process, then at the same time, the entropy of some other system increases. Thus, when all the systems are taken together as the universe, the entropy of the universe always increases.

$$\Delta S_{system} + \Delta S_{surroundings} \geq 0$$

or

$$\Delta S_{universe} \geq 0$$

(b) A heat engine performs 100 J of work and at the same time reject 400 J of heat energy to the cold reservoir. What is the efficiency of the engine? (3)

Ans **Data:**

$W = 100J$

$Q_2 = 400J$

$\eta = ?$

Solution:

$$\eta = \frac{W}{Q_1}$$

$$W = Q_1 - Q_2$$

$$Q_1 = W + Q_2$$

$$= 100 + 400$$

$$= 500J$$

$$\eta = \frac{100}{500} \times 100$$

$$= 20\%$$

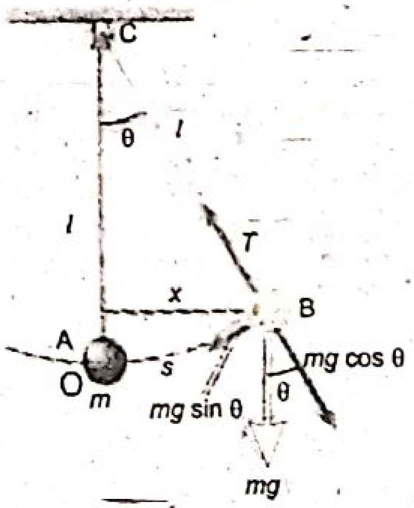
Q.8.(a) What is simple pendulum? Show that its motion is simple harmonic. Also derive an expression for its time period. (5)

Ans **Simple Pendulum:**

A simple pendulum consists of a small heavy mass *m* suspended by a light string of length *l* fixed at its upper end, as shown in Fig. When such a pendulum is displaced from its mean position through a small angle θ to the position B and released, it starts oscillating to and fro over the same path. The weight mg of the mass can be resolved into two components; mg sin θ along the tangent at B and mg cos θ along CB to balance the tension of the string. The restoring force at B will be:

$$F = -mg \sin\theta$$

When θ is small, $\sin\theta \approx \theta$



So $F = m\,a = -m\,g\,\theta$ (1)

or $a = -g\,\theta$

But $\theta = \dfrac{\text{Arc AB}}{l}$

When θ is small Arc AB = OB = x, hence $\theta = \dfrac{x}{l}$

Thus, $a = -\dfrac{gx}{l}$ (2)

At a particular place, 'g' is constant and for a given pendulum, 'l' is also a constant.

Therefore, $\dfrac{g}{l} = k$ (a constant)

and the motion of the simple pendulum is simple harmonic. Comparing eq. (2) with $a = -\omega^2 x$

$$\omega = \sqrt{\frac{g}{l}}$$

As time period $T = \dfrac{2\pi}{\omega}$

Hence, $T = 2\pi\sqrt{\dfrac{l}{g}}$ (3)

This shows that the time period depends only on the length of the pendulum and the acceleration due to gravity. It is independent of mass.

(b) An organ pipe has a length of 50 cm. Find the frequency of its fundamental note and the next harmonic when it is opened at both ends. Speed of sound = 350 ms^{-1}. (3)

Ans **Data:**

$v = 350$ m/s

$l = 50$ cm $= 0.5$ m

(a) $\left.\begin{array}{l} f_1 = ? \\ f_2 = ? \end{array}\right\}$ When it is opened at both ends.

(b) $\left.\begin{array}{l} f_1 = ? \\ f_2 = ? \end{array}\right\}$ When one end is closed, other end is open.

(a) When organ pipe open at both ends:

then, $f_1 = \dfrac{v}{2l}$

$$f_1 = \frac{350}{2 \times 0.5}$$

$$f_1 = \frac{350}{1}$$

$$f_1 = 350 \text{ Hz}$$

$$\therefore \quad f_2 = 2f_1$$

$$f_2 = 2 \times 350$$

$$f_2 = 700 \text{ Hz}$$

(b) When it is closed at one end:

$$f_1 = \frac{v}{4l}$$

$$f_1 = \frac{350}{4 \times 0.5}$$

$$f_1 = \frac{350}{2}$$

$$\boxed{f_1 = 175 \text{ Hz}}$$

$$f_2 = 3f_1$$

$$f_2 = 3 \times 175$$

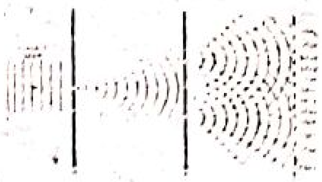
$\boxed{f_2 = 525 \text{ Hz}}$

Q.9.(a) Discuss in detail the Young's double slit experiment to study the interference of light. (5)

Ans **Young's Double Slit Experiment:**

Young's double slit experiment was devised by Young for studying interference effects of light. A screen having two narrow slits is illuminated by a beam of monochromatic light. The portion of the wave-front incident on the slits behaves as a source of secondary wavelets (Huygen's principle). The secondary wavelets leaving the slits are coherent. Superposition of these wavelets result in a series of bright and dark bands (fringes) which are observed on a second screen placed at some distance parallel to the first screen.

Let us now consider the formation of bright and dark bands. As pointed out earlier, the two slits behave as coherent sources of secondary wavelets. The wavelets arrive at the screen in such a way that at some points, crests fall on crests and troughs fall on troughs resulting in constructive interference and bright fringes are formed. There are some points on the screen where crests meet troughs giving rise to destructive interference and dark fringes are thus formed.



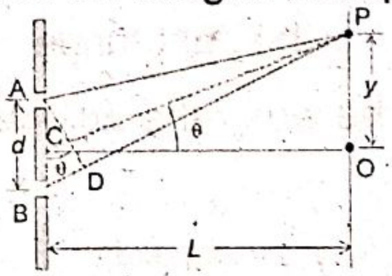
The bright fringes are termed as maxima and dark fringes as minima.

In order to derive equations for maxima and minima, an arbitrary point P is taken on the screen on one side of

the central point O. AP and BP are the paths of the rays reaching P. The line AD is drawn such that AP = DP. The separation between the centres of the two slits is AB = d. The distance of the screen from the slits is CO = L. The angle between CP and CO is θ. It can be proved that the angle BAD = θ by assuming that AD is nearly normal to BP. The path difference between the wavelets, leaving the slits and arriving at P, is BD. It is the number of wavelengths, contained within BD, that determines whether bright or dark fringe will appear at P.

Constructive Interference:

If the point P is to have bright fringe, the path difference BD must be an integral multiple of wavelength.



Thus, $BD = m\lambda$, where $m = 0, 1, 2, ...$

Since, $BD = d\sin\theta$

Therefore, $d\sin\theta = m\lambda$ (1)

It is observed that each bright fringe on one side of O has symmetrically located bright fringe on the other side of O. The central bright fringe is obtained when m = 0.

Destructive Interference:

If a dark fringe appears at point P, the path difference BD must contain half-integral number of wavelengths.

Thus, $$BD = \left(m + \frac{1}{2}\right)\lambda$$

Therefore, $$d\sin\theta = \left(m + \frac{1}{2}\right)\lambda \quad (2)$$

The first dark fringe, in this case, will obviously appear for m = 0 and second dark for m = 1.

If the angle θ is small, then

$$\sin\theta \approx \tan\theta$$

$\tan\theta = y/L$, where y is the distance of the point P from O. If a **bright fringe** is observed at P, then, we get,

$$y = m\frac{\lambda L}{d} \qquad (3)$$

If P is to have **dark fringe**, it can be proved that,

$$y = \left(m + \frac{1}{2}\right)\frac{\lambda L}{d} \qquad (4)$$

In order to determine the distance between two adjacent bright fringes on the screen, mth and $(m + 1)$th fringes are considered.

For the mth bright fringe, $y_m = m\frac{\lambda L}{d}$

and for the $(m + 1)$th bright fringe $y_{m+1} = (m+1)\frac{\lambda L}{d}$

If the distance between the adjacent bright fringes is Δy, then

$$\Delta y = y_{m+1} - y_m = (m+1)\frac{\lambda L}{d} - m\frac{\lambda L}{d}$$

Therefore, $\Delta y = \frac{\lambda L}{d}$

(b) A glass light pipe in air will totally internally reflect a light ray if its angle of incidence is at least 39°. What is minimum angle for total internal reflection if pipe is in water (n = 1.33)? (3)

Ans **Data:**

Angle of incidence for glass = θ_c = 39° (for air-glass)

Angle of incidence of water = θ_1 = ?

So,

Using the formula for refractive index of glass-air interface:

$$n_1 = \frac{1}{\sin\theta_c}$$

Putting the values,

$$n_1 = \frac{1}{\sin 39^\circ} = \frac{1}{0.629} = 1.59$$

$$\boxed{n_1 = 1.59}$$

Using Snell's law for glass-water interface,

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Where, n_1 = is the refractive index of glass = 1.59

n_2 = refractive index of water = 1.33

θ_1 = the angle of incidence or critical angle.

$\theta_2 = 90^\circ$ for total internal reflection.

Putting the values, we get

$$1.59 \times \sin \theta_1 = 1.33 \times \sin 90^\circ$$

$$\sin \theta_1 = \frac{1.33 \times 1}{1.59} = .84$$

$$\theta_1 = \sin^{-1}(0.84)$$

$$\boxed{\theta_1 = 57^\circ}$$